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## UTM, ATM, STM... slices of the sky?

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# UTM, ATM, STM... Slices of the Sky?

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## Abstract

This paper will examine the functional differences between Unmanned Aircraft Traffic Management Systems, Air Traffic Management Systems, and Space Traffic Management. Understanding both the similarities between the systems and the different functional requirements of each concept is critical in the discussion and development of STM. While there are many commonalities in each area, it is important to understand how the different environments affect the ability to develop policies, procedures and technologies to manage the vehicles operating in the distinct environment. Both technical and legal frameworks will be discussed.

Building a conceptual framework for STM can benefit from an understanding of the development of existing ATM and identifying where a similar evolutionary strategy can be applied. Considering questions like: How much STM is necessary and when, who can provide the service, how can it be funded, and what international agreements are necessary? These are foundational to the development of realistic policies to promote sustainability in space traffic management.

## 1. Introduction

As outer space, particularly low earth orbit, becomes an increasingly congested and competitive environment, discussions of the development of a space traffic management system are occurring. These discussions bring natural comparisons to air traffic management systems to identify possible models for system architecture. The current state of air traffic management is a robust, structured, regulated and established system with an extraordinary safety record. It is natural to seek to apply this approach to other operating environments. For low altitude, small-unmanned aircraft operations, similar discussions are occurring in an effort to create an unmanned aircraft systems traffic management system. In examining the validity of ATM as a model for UTM and STM, certain assumptions should be addressed. Are the operating environments sufficiently similar for ATM to provide a useful model? Is the primary difference between the operating environments the level in which the operations occur? Are they just slices of

the same sky? Can we extrapolate the standards from one operational environment and apply it to the others? To answer these questions, it is necessary to understand the unique characteristics of each environment.

## **2. The Operating Environments**

This paper discusses the airspace management elements of operations in these environments and does not address the privacy, legal and environmental issues that would also be considered in developing a regulatory framework.

### **2.1. Unmanned Traffic Management**

The NASA concept of Operations for UTM focuses on low altitude operations of unmanned aircraft in uncontrolled airspace.<sup>1</sup> It is noted that uncontrolled airspace is not synonymous with unregulated airspace. The FAA has defined airspace classes that establish the requirements for an operator to operate within the defined class. Class A airspace requires that all aircraft operate under Instrument Flight Rules, IFR, and Air Traffic Control (ATC) provides separation services. Subsequent classes have fewer operating requirements and mixed operations are allowed in airspace classes from B through E. In Class E, both IFR and Visual Flight Rules (VFR) are permitted and VFR operations can be participating and non-participating (aircraft not identified by or in contact with ATC). Class G airspace is uncontrolled, indicating that no air traffic separation services are provided.

Building a UTM system in uncontrolled airspace relies on the existing authority of the Federal Aviation Administration to regulate operations in the airspace. The NASA UTM concept does not envision the creation of a new airspace class.

#### **2.1.1. Description of Operating Environment**

Class G, uncontrolled airspace, is defined in the US as airspace that is not otherwise classified as Class A, B, C, D or E. It is generally the airspace below 1,200 feet above ground level (AGL) and outside the vicinity of airports. While this airspace is often considered unoccupied, that is not correct. It contains diverse operations that are both commercial and recreational in nature. They include manned helicopters, gliders, light sport and experimental aircraft as well as unmanned operations. In addition to the hazards to aircraft from other operators, the environment also has hazards from terrain and obstructions that do not present problems at higher altitudes.

While the FAA has the authority to regulate operations in this airspace, it has historically taken a light touch approach to regulation. For general aviation aircraft, attempts to impose regulations on low-end recreational users have been challenged by the operating community. Notably, in 1988, the FAA proposed a mandate for aircraft operating above 6,000 feet AGL or 12,500 mean sea level (MSL), whichever is lower, to be equipped with a Mode C transponder as a safety measure following a mid air collision between an airliner and a small aircraft. Public responses from the recreational pilot community resulted in a watering down of the proposal, requiring the transponders only above

10,000 MSL and in the vicinity of busy airports.<sup>ii</sup> This example illustrates the general aversion to equipment mandates within FAA.<sup>1</sup>

Often, the prediction of growth in the sale of small UAS drives a reactionary concern, indicating that the need for UTM services may be considerably greater than that of manned aviation based on sheer numbers of aircraft. It is important to consider the context of the operations. The projected number of small UAS is less significant than the projected operating hours. In drawing parallels to manned operations, the average commercial airliner aircraft will have 2,525 operating hours per year<sup>iii</sup> while the average general aviation aircraft (including on demand air taxis) will have only 114 operating hours per year.<sup>iv</sup> The number of aircraft does not provide an appropriate means to compare airspace demand from manned to that of unmanned aircraft, in order to make an apples-to-apples projection of airspace traffic density information on projected operating hours for UAS is needed. Understanding the projected usage of both recreational and commercial UAS will be an important step in describing the operational environment.

### 2.1.2. Types of Operators

Traditional aviation operators are both commercial and recreational users who operate under VFR regulations. Operations are conducted in visual meteorological conditions (VMC), defined visibility conditions that allow the pilot onboard the aircraft to see and avoid traffic, obstacles, and terrain. Aircraft types include helicopters, fixed wing aircraft, gliders, parafoils, and aerostats. Currently, unmanned aircraft are operated within visual line of sight of the ground operator (VLOS) however progress is being made to allow routine operations beyond visual line of sight (BVLOS). The underlying premise of VLOS operations is that the ground operator will be able to detect hazards from traffic, obstacles, and terrain in a manner similar to that of the pilot onboard an aircraft. This places a significant operational burden on the industry. The development of high value commercial and public safety applications for drones increases the need for the airspace to accommodate BVLOS operations in non-segregated airspace.

Statistical data on operators in uncontrolled airspace is limited, as flight hours are not tracked for recreational operations, although aircraft are registered. For unmanned aircraft, the registry has encountered difficulty. For recreational users, the registry required the operator to register, but unlike other aviation users, it was not required to register each aircraft. Considering a single operator could have many unmanned aircraft, even though the registry had over 700,000 registered operators, it did not provide a clear insight into the total number of operating aircraft. In addition, the requirement for recreational users to participate in the registry was challenged under the assertion that the FAA did not have the legal authority to regulate recreational drones, considered as model aircraft. Commercial drones are subject to registration and more than 20,000 have been registered.<sup>v</sup>

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<sup>1</sup> The current ADS-B mandate for all aircraft to equip with ADS-B transponders by 2020 will not apply to aircraft that are not required to have a transponder under existing rules.

### 2.1.3. Regulatory Authority and Access

The challenge to the drone registry is indicative of an ambiguity in the FAA regulatory mandate as it relates to low altitude airspace. While the FAA has clear authority over the public airways, the question of where private air rights end and the public airways begin has been a matter of legal debate since the 1930's. The Supreme Court in *US vs. CAUSBY*, in 1946, held that the immediate airspace over private land is that of the property owner but that navigable airspace must be free for public access. The court held that *"The air above the minimum safe altitude of flight prescribed by the Civil Aeronautics Authority is a public highway and part of the public domain, as declared by Congress in the Air Commerce Act of 1926, as amended by the Civil Aeronautics Act of 1938"* in establishing the base of the public airways as the minimum safe altitude for flight and *"Flights below that altitude are not within the navigable air space which Congress placed within the public domain, even though they are within the path of glide approved by the Civil Aeronautics Authority"*<sup>vi</sup> This ruling reflected the change in public policy thinking in response to the introduction of new technology, the airplane. However, the emergence of small UAS may change how the FAA defines the minimum safe altitude for flight as the altitudes prescribed in the 1930's did not contemplate the use of small, unmanned aircraft.

Developments in small UAS and their operation at low altitude have created new regulatory demands, but FAR 91.119, continues to hold that:

"Except when necessary for take off and landing, no person may operate and aircraft below the following altitudes:

(a) *Anywhere*. An altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.

(b) *Over congested areas*. Over any congested area of a city, town, or settlement, or over any open air assembly of persons, an altitude of 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet of the aircraft."

(c) *Over other than congested areas* – An altitude of 500 feet above the surface except over open water or sparsely populated areas. In that case, the aircraft may not be operated closer than 500 feet to any person, vessel, vehicle, or structure.

However, exceptions to this regulation exist, most notably, helicopters:

(d) *Helicopters* – Helicopters may be operated at less than the minimums prescribed in paragraph (b) or (c) of this section if the operation is conducted without hazard to persons or property on the surface. In addition, each person operating a helicopter shall comply with routes or altitudes specifically prescribed for helicopters by the Administrator.

Historically, FAA has promulgated different operating standards for helicopters than for fixed wing aircraft noting the considerable differences in operating characteristics and

public safety applications, “the helicopter's increased use by law enforcement and emergency medical service agencies requires added flexibility.”<sup>vii</sup> While these provisions may be interpreted to apply to the rotorcraft UAS community, other enabling legislation has been enacted to allow for the regulation of UAS operations more broadly. However, the airspace authority remains ambiguous. Landowners will argue that the immediate airspace above their property is not within the navigable airspace of the United States and as a result is not subject to FAA authority. The questions of whether a property owner can operate a UAS over their property without restriction and whether that property owner has the ability to prevent operations in the same manner they are able to prevent other forms of trespassing, remain unanswered.

The FAA has been successful in arguing that public safety dictates that restrictions or prohibitions on the operation of unmanned aircraft in the vicinity of airports (controlled airspace) are necessary. However, the demand for commercial drone services in congested environments point to a need to allow for the safe operation of unmanned aircraft in these areas rather than the prevention of their use. That is not to say that IFR separation services are needed, however provisions are needed to ensure safety in a controlled mixed environment. In addition, operational differences, safety analyses, and existing provisions for air traffic control indicate that there is a need for a new structure for the provision of services to ensure the safe operation of unmanned aircraft specific to uncontrolled airspace.

#### **2.1.4. Barriers**

There is a lack of regulatory clarity between property rights and public access. While there may be an emerging consensus that the system of UTM is necessary for public safety, issues related to privacy, noise, and property rights may interfere with the development of a safety based regime<sup>viii</sup>. This is not unprecedented in aviation. Many airports are faced with environmental limits, particularly those related to noise, that are in conflict with procedures that would increase both safety and efficiency in airport operations.

Funding considerations create a barrier in any area where new services are necessary. An expansion of the existing air traffic control system would impose additional costs on the air navigation service provider. In addition, it is unclear what services would be required in uncontrolled airspace. The diversion of resources from the primary mission of the FAA Air Traffic Organization (ATO) to provide air traffic separation services could meet with resistance. However, the mandate is not limited to separation services, it is more broadly to provide for the safe, orderly and expeditious flow of air traffic, illustrating that it cannot be removed from the equation. In considering how UTM is to be developed, it is important to consider the role of the ATO as a service provider. As the ATO is within the FAA, it is possible for the FAA to consider whether UTM should be provided by FAA through ATO or whether an additional air navigation service provider should be established for the provision of services in low altitude, uncontrolled (Class G) airspace.

As the overwhelming majority of drone owners are recreational, we can anticipate resistance to regulatory requirements and equipment mandates. This was evident in the

challenge to the drone registry. It is important to distinguish between the recreational operator and the commercial operator in this regard. Historically, the recreational operator has been the most resistant to regulation as any additional costs are born wholly by the owner/operator. In contrast, the commercial operator is often more willing to participate in creating an appropriate regulatory framework as it provides both operational certainty and creates an insurable activity. Regulatory costs can be passed on to, or shared by, the consumer of drone services. However, the funding of operational safety services is controversial. For air traffic services, the FAA has experienced decades long battles over the operator contribution to funding air traffic services. The question of whether ATC is a public safety service provided for the general good or a service provided to the user community is a matter of debate in determining whether an excise tax or user fee is the more appropriate funding mechanism.

The question emerges of whether a UTM system that serves commercial users, but does not place an undue burden on recreational users or other airspace users can meet the safety challenges in uncontrolled airspace. It is also necessary to consider whether this service should be provided by government, a single operator, or on an operator-to-operator basis. Can multiple providers exist, with responsibility for different geographical areas or is it necessary for a one size fits all solution? What role can public private partnerships play in meeting this need? These open policy questions create a barrier to the development of UTM.

## 2.2. Air Traffic Management

The Air Traffic Management System in the United States is a well-established, regulated system that is generally well understood by the operators in the system. It has evolved over time, in partnership with the aviation industry. Both operating rules and air traffic service provision are well known and understood by the community. The system of navigable airways allows for a structured system to provide separation from traffic, terrain and obstacles through the use of published restrictions and procedures. The distribution of responsibility between air traffic controller and aircraft pilot is delineated. Airspace classes provide clarity for operators and define both equipment requirements and services provided.

### 2.2.1. Description of Operating Environment

The operating environment for the air traffic management system in the US is the National Airspace System (NAS), which is defined as “*NATIONAL AIRSPACE SYSTEM— The common network of U.S. airspace; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information, and manpower and material. Included are system components shared jointly with the military.*”<sup>ix</sup>

The operating environment includes diverse types of manned aircraft, including civil, military, recreational, and business aviation. It also includes unmanned aviation that is authorized to operate in the airspace. Airspace is divided into airspace classes within



which air traffic services are provided. Airspace ranges from high density to remote and oceanic airspace and includes both surveillance and non-surveillance airspace.

#### **2.2.1.1. Upper E**

Recent developments in high altitude unmanned aircraft and commercial space operations have increased the demand in airspace above Flight Level 600 (60,000 ft.). This airspace is designated as Class E, which means that both VFR and IFR operations are permitted and air traffic services are provided. However, as this airspace is above Class A, which is restricted to IFR operations, it is unclear whether the regulatory framework for Class E airspace at lower altitudes is appropriate for Class E above Class A. Discussions are ongoing to determine if a new category of “Upper E” airspace is needed. In addition, while FAA has provided air traffic services above FL600 for several decades, traffic has been predominately military operations. Other operations, like unmanned balloons and experimental operations have been permitted through the FAA waiver processes.

Class E permits VFR operations, however regulations that would allow VFR operations for unmanned aircraft at these altitudes have not yet been developed. In addition, the diversity of operational types, ranging from balloons to rockets and including high endurance, high altitude pseudo-satellites creates an environment that is substantially different than that used for traditional aviation. These new entrants may require a new paradigm for air traffic services. As this is an emerging area, the description of ATM in this paper will focus on the traditional aviation sector and airspace at and below FL600.

#### **2.2.2. Types of Operators**

Operators in this airspace are predominately traditional manned aviation. While there are diverse operational types, the airspace and regulations are designed for manned aviation and anticipate a forward trajectory. Provisions are made for special operations, including gliders, parachute jumping, and unmanned free balloons. However, the underlying principles to maintain the safe, orderly and expeditious flow of aircraft and allow access to all user types depends on a common set of rules of the air. Commercial, recreational and military types operate in shared airspace. Segregated airspace is used to accommodate certain military activities and hazardous operations. Commercial space operations are accommodated through the use of segregated airspace.

#### **2.2.3. Regulatory Authority and Access**

The FAA is the established regulatory authority and includes the air navigation service provider, the Air Traffic Organization (ATO). Any restrictions to airspace access are based on a safety of flight analysis and the airspace itself is regulated as a non-depleting public commons. Airspace access is distinct from airport access, as airports can be public or private, and airport services, as distinct from air traffic control services, are provided on a commercial basis.



#### **2.2.4. Barriers**

This is the most established of the traffic management systems described in this paper. The barriers to change or evolution of the system are primarily political or cultural. The FAA aversion to equipment mandates discussed earlier slows progress of modernization efforts. For example, the implementation of reduced vertical separation minima (RVSM) in the US lagged behind the FAA's European counterparts in order to extend the time available for the industry to comply with onboard equipment requirements. The FAA still allows VFR aircraft to operate without a transponder below 10,000 feet over more than 90% of the US. Finally, while the navigational infrastructure is transitioning from a ground based network to satellite based navigation (GPS); the FAA continues to permit commercial operations without GPS navigation capabilities. The need to accommodate the least equipped user affects investment decisions by both service provider and operators. For example, users that have equipped with advance performance based navigation systems are unable to realize full benefits from the investment when operating in a mixed equipage environment. The FAA cultural predisposition to ensure that systems can accommodate the least equipped user can result in airspace inefficiency. As the ATM system becomes increasingly strained, this approach may become unsustainable.

### **2.3. Space Traffic Management**

Space traffic management is the least developed of the three categories. Given that the overwhelming majority of congestion in Earth's orbit is from debris, it is not clear that space can be effectively "managed" in the context of traffic management as discussed in the other two categories. Rather, space traffic management may be a term applied to describe the provision of conflict detection and alerting services as well as the development of a set of standards to reduce the potential creation of additional debris.

#### **2.3.1. Description of Operating Environment**

In general, discussions of space traffic management refer to the portion of space where objects are in orbit around the Earth. Deep space is not regarded as sufficiently congested to warrant substantive policy discussion on the topic, with the exception of the need for deep space activities to safely transit the orbital domain. However, some have used the term to refer to the management of space operations, which would include the launch and recovery phases. As this activity occurs within the airspace defined as the NAS, this paper considers those activities to occur within the ATM system (where they are currently accommodated through the use of segregated airspace) and not part of STM.

The orbital space operating environment is evolving as the commercial space sector grows. The growth in the small satellite market is increasing the number of operational satellites in low Earth orbit by orders of magnitude. The size of planned constellations includes hundreds, rather than tens, of satellites. Debris from man-made objects placed in orbit continues to increase. There are currently more than 500,000 space objects tracked orbiting the Earth. However, NASA's chief Scientist for Orbital Debris considered non-

trackable objects to be the greatest risk to space missions.<sup>x</sup> Collisions between satellites are not only costly to the operators, but also create new debris, increasing the risk to other operators seeking to operate in or transit the orbital domain.

### **2.3.2. Types of Operators**

Functioning satellites and rockets transitioning through orbital space are the products of a diverse set of operators. Like the other environments described, they include commercial to non-commercial operations. Noncommercial operators include research institutions, governments, educational institutions and military and security entities. Commercial operations are dominated by telecommunications and earth sensing services. Orbital debris is any man made object orbiting the Earth that no longer serves a useful purpose. While the debris was the result of operator's actions, it is unclear how it should be defined once it is not part of a functioning space object.

### **2.3.3. Regulatory Authority and Access**

Under international treaties, there is no restriction on access to space. Space is considered a global commons for which no State can exert a claim of sovereignty. However, each State is required to provide appropriate safety regulation for space operators who launch from that State, so it is imprecise to say there is no restriction. More precisely, there is no one State or intergovernmental body with regulatory authority over space and a State cannot preclude access by operators from another State of launch. Various administrative and legal regimes exercise authority over space operators, but do not constitute regulatory authority over on orbit activities.

### **2.3.4. Barriers**

The barriers to the development of a Space Traffic Management regime begin with the absence of a centralized authority with a legal right to manage the space environment. The structure of international standards and governance does not parallel that of air traffic management. While both aviation and space have international treaties managed by the United Nations, the structures of the treaties are very different. The various space treaties are structured to promote peaceful use and address liability concerns, while the aviation treaty is dominated by the creation of common standards and recommended practices for the operation of civil aviation between States. Absent an international agreement that establishes authority to create a space traffic management regime, it is unclear how the concept could progress.

If the concept of space traffic management is narrowed to consider situational awareness at its core, the development of conjunction alerting and advisory services frameworks may be possible. However, this approach is not without barriers. The requirement for a satellite to execute an avoidance maneuver resulting from a conjunction alert implies a regulatory mandate. Policies that establish voluntary compliance structures could be used to overcome this barrier. However, like any cooperative international activity, identifying the necessary resources to plan and implement a system with globally distributed benefits presents a challenge.

### 3. Building a Space Traffic Management System

In order to build a space traffic management system, it is important to first determine what is meant by the term. Essentially, you must answer the question, how much STM is necessary? In “*Evolving Space Situational Awareness*” presented to the International Association for the Advancement of Space Safety, the following terms for elements of STM were presented:

*SSA (Space Situational Awareness) – the detection, collection and dissemination of information on the location and trajectory of natural and manmade objects in orbit around the Earth.*

*CAA (Conjunction Assessment and Alerting) – the evaluation of natural and manmade objects in Earth’s orbit to identify potential collisions and notification of operators to determine if avoidance maneuvers are necessary.*

*STM (Space Traffic Management) – the control of the orbital environment by an appropriate authority responsible for the prevention of collisions between operational satellites and natural or man made objects.*

Particularly in the near term, the need for SAA and CAA is emerging. As an advisory service, the absence of a regulatory authority does not present the same legal, political and policy barriers as a STM that more closely resembles the ATM system. Both STM and UTM raise the question of whether it is a public safety service or a commercial service to be provided to operators. Arguments can be made for each. While, with the exception of the International Space Station and related activities, space activities are unmanned and a collision in space does not present a direct risk to loss of life, a safe and viable orbital environment is essential for the provision of critical services from space. An argument can be made that loss of vital services from space operations could pose a direct safety threat to people on earth.

Once the question of how much STM is needed is answered, it becomes possible to consider other legal and policy questions: who could be the provider, how is the system funded, and what international agreements are necessary? These policy questions will affect the development of an operational concept. An advisory service is a very different concept of operations than one under a regulated framework. The development of industry standards can substitute for regulatory mandates if it is done within the context of a willing industry. The space community has reached a consensus that congestion in low Earth orbit presents a risk to continued safe operation. Voluntary participation in a regime to prevent conjunctions between space objects already exists. As a result, the transition to a regulated process may not be necessary.

The concept of single provider, used in ATM may present an unnecessary barrier to STM in this context. Governments and other large-scale operations that provide tracking of space objects could make the data available on a free and open basis, similar to that of the

LandSat and Copernicus satellite programs. This could lead to the development of the industry.

The development of competitive providers of CAA could spur innovation, and ensure that the technologies for STM keep pace with innovation in the industry. In this way, the STM concept of operations can break away from that of ATM. The ATM system relies on common standards for communication, navigation and surveillance. For STM, the systems can rely on shared information from multiple sources to create the situational awareness picture. In the ATM environment, there is a dependence on cooperative surveillance, in which each participant is required meet specific equipment requirements. For STM, the majority of space objects and debris will be non-participating. As a result, the participatory surveillance model is not appropriate for STM applications. However, this creates an opportunity to develop systems that have interoperability, but do not necessarily require commonality.

For STM, conjunction assessment and alerting is not a tactical activity in the same way it is done for aircraft separation in ATM. The response to a conjunction alert allows time for assessment of the risk and a decision making process, whereas the ATM conflict resolution process requires timely compliance with an air traffic control instruction. This is a significant difference and moves away from the need for a single service provider to preclude the risk of conflicting information from different sources. Since the response is predicated on a risk based decision from the satellite operator, rather than create conflict, the operator may see benefits from receiving information from multiple sources.

#### 4. Comparison of Operating Environments

While the operating environments for UTM, ATM and STM share the common goals of safe operation and collision avoidance, there are differences that preclude the assumption that the principles used in one domain can be exported to the others.

	Regulated	Controlled	Occupied	Obstacles	Tactical Control	Collision Alerting	Governance
UTM	Yes	No	Yes	Unidentified	No	Yes	State based
ATM	Yes	Yes	Yes	Identified/Regulated	Yes	Yes	State based
STM	No	No	Yes	Debris/Tracked	No	Yes	International

As a matter of comparison, UTM and ATM are more similar to each other than either are to STM. While there are distinct differences that need to be considered from a policy perspective, the technical capacity to build an UTM system that mirrors the concepts in an ATM system exists. The primary barriers are legal, political and economic; whereas the barrier to STM that could be compared to ATM is physical. While they both may be designed to accommodate non-participating operators, neither ATM nor UTM consider debris as a primary collision risk. Nonfunctional occupants in the operational environment preclude the use of regulatory practices or standards to constrain behavior. Prevention of debris creation or the cleanup of the orbital environment is important risk mitigation, however it is not STM as is understood in an operational context.

## 5. Conclusion

Space traffic management is a distinct category of service and while there are certain commonalities in concepts between ATM and UTM, the existence of debris as the primary risk to be mitigated necessitates a unique concept of operation. The “management” of an operating environment within which the majority of occupants are uncontrolled and non-functional is not comparable to an environment where the airspace users are known, cooperative and subject to regulation. In developing STM, a blank slate approach to a concept of operations will likely provide a more efficient path forward than an attempt to model one after an ATM system.

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